Journal of Cleaner Production 219 (2019) 981–993

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Analysis of energy related CO_2 emissions in Pakistan

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ARTICLE INFO

Article history:
Received 16 July 2018
Received in revised form
5 January 2019
Accepted 11 February 2019
Available online 13 February 2019

Keywords:
CO_2
Fossil fuel consumption
Total energy consumption
Clean energy
LMDI

ABSTRACT

CO_2 (carbon dioxide) emissions from fossil fuels have turned out one of the most perilous and complex issues driving the climate change debate. The issue of increasing demand for electricity at the same time reducing CO2 emissions has become important worldwide. This study evaluates the CO_2 emissions from the power sector of Pakistan during 1978–2017 using Logarithmic Mean Divisia Index technique and scenario analysis. We estimate LMDI to check the change under prearranged elements. According to results, the shift in population, activity effects, and gross domestic product are the essential factors in charge of the increase in CO_2 emissions while carbon intensity and energy intensity effects participate in cutting emissions. Finally, scenario analysis found overall activity increases due to population and intensity of CO_2 emissions, but carbon intensity could be reduced by using cleaner energy technologies. The findings suggest that CO_2 emissions will possibly arrive at 277.9 Mt in 2035 in Pakistan. In relation with the main findings, some targeted policies suggestions are provided.

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1. Introduction

Environmental variation alludes to the improved attention of Green House Gasses (GHGs), mainly carbon dioxide (CO_2) in the earth's climate resulting in global warming. GHGs include methane, nitrous oxides, CO_2, ozone and water vapor. The CO_2 outflows formed by personal behavior arrive from the combustion of fossil fuels about soil attrition, deforestation, animal breeding, and agriculture, etc. Lin and Ahmad (2017). In 2014, the emission of worldwide GHGs was accredited to the power sector. According to IEA (2017), this includes the share of 90% for CO_2, 1% for N_2O and 9% for CH_4 and 14% for other gases. Climate change affects weather changes, household income, poverty, fields and forest products, local livelihoods, household income and income of field growth (Ali et al., 2017). According to Baig and Baig (2014), the environmental change weights generate immediate sway on diverse sectors of Pakistan including water availability, harvests pattern, livestock, forests, biodiversity, coastal zones and so forth. Therefore, this is one of the most perilous and multifaceted environmental issues. To alleviate the impacts from claiming of atmosphere change; the worldwide society is determining to bound the global intended temperature to 2 °C until the present century. Those guarantees, overall called as the Intended Nationally Determined Contributions (INDCs), presented via distinctive nations to the twenty-one conference of the Parties (COP21) for atmosphere variation in December 2015, are serious to accomplishing the objective. The concentration was to deal with the CO_2 emission of individual nations, avoiding the most horrible bumps of environmental change. Among the list of few countries; Pakistan is also defenseless to the upshots of climate change (see Table 1). A report by Eckstein et al. (2017) identified that Pakistan is persistently affected by climate change and extreme weather events. This unprecedented experience and substantial change in climate/weather have resulted in the loss of over US$9.6 billion to the economy of Pakistan since 2010 (Pakistan CPEIR, 2017). The government of Pakistan approves a strategy archive in 2014. According to Khan (2014) and Lin and Ahmad (2016), the vision focuses on putting Pakistan around the highest the topmost twenty-five countries with admiration to economic growth, rise energy access (i.e. as of 67%–90% of the populace) and alleviate climate change. Although Pakistan contributes 0.8 per cent of worldwide emanations, the Government of Pakistan (GOP) is dedicated to change in atmosphere, by alteration techniques as by plummeting GHGs discharge. Power, transportation, forestry, farming worker & livestock, town arranging and manufacturing zone are the mean locations. These are necessary to be arbitrating in place to alleviate the impacts of climate. INDC found its roots within the Pakistan (Commission, 2015; National Climate Change Policy, 2012). For the past several years, Pakistan

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https://doi.org/10.1016/j.jclepro.2019.02.112
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Table 1
Climate change threats to Pakistan (National Climate Change Policy, 2012).

Serial no.	Threats
1	Unpredictable monsoon rains dangerous floods and droughts significantly boost the frequency and intensity of such weather.
2	CO2 emission, global warming and transboundary pollution sources collapse the glaciers of Hindu Kush-Karakoram and Himalayan (HKH).
3	Many floods can occur due to an increase in siltation of major dams.
4	The arid and semi-arid agricultural areas will affect and condensed productivity.
5	The decrease in the growth of plantation.
6	Because of the climb of ocean level, an increased intrusion of saline water in the Indus delta.
7	Some threats to food, health, water, security and energy.

has been entrenched in power adversity. In 2016, Pakistan's prime power contribution was 83.2Mtoes (million tons of oil equivalents). According to Pakistan Energy Yearbook (2016), the energy contribution comprises of oil (27.5%), gas (40.9%), liquid petroleum gas (0.3%), coal (5.4%), hydro energy (7.7%), nuclear energy (1.3%) and renewable 0.4 Mt. Lin and Ahmad (2017) investigated that about two decades ago; Pakistan's power supply mainly comprises from claiming hydro vitality.

The purpose of this article has been to investigate the CO_2 emissions in the power sector of Pakistan. For the protection of the environment, short-term and long-term emission reduction policies are made (i.e. solar and thermal power) whose successive objectives are regarding the balance of payment (BoP), economic growth (EG), energy security (ES), and environmental sustainability (Env. S). Also, the power administration is still battling to contract with the power disaster similarly because the power setback surpasses 2888 MW in June 2017. Currently, in May 2018, the shortfall reached (6000–7000 MW), and load shedding has increased up to five hours (The Nations Pakistan, 2018).

According to Vision (2025) (2014), Pakistan has approved the objectives of expanding monetary growth, environmental change alleviation, and a decrease in energy poverty. The objective is to improve the betterment of BOP, EG, ES and environmental sustainability. This is also expected to be partly driven by the last decade exploitation of the country's precious coal assets. Worth of $46b China Pakistan Economic Corridor (CPEC) frequently comprising of power tasks ($ 33.8b) has been signed. At an initial stage, the power schemes comprise coal power projects (worth of 7560 MW) and cleaner energy development tasks (capability of 2790 MW). The cleaner power ($8.8 billion) and coal plans are (value of $6.4b) correspondingly. Particularly coal has elevated carbon substance; a superior offer of coal power plans comparative to renewable energy projects has rigorous ecological suggestions that might make essential setback for weather change mitigation (Lin and Ahmad, 2017; Pakistan Economic Survey, 2016–17).

The dull execution in the precedent, present and the prospect standpoint of Pakistan's energy design-build new circumstance for the change administration. Wang et al. (2018) posit that it is, therefore, can be seen that CO_2 is answerable for almost 58.8% of the global warming and environmental progressions. According to Assembly (2011), the results of climate change are amalgamating with the varying human geology in the world. As a result, Pakistan could not identify actual carbon diminishment arrange in its promise to the COP-21. Also, the carbon relieving guarantee is the theme to “affordability, procurement of global climate finance, relocates of building capability and technology (INDC, 2015). Although, this furious the atmosphere pro at the nation. They have confidence that Pakistan might have assured for strong focuses without undermining the advancement objectives. It may be further accepted that the promise, i.e. INDC (2015) may be going starting with an additional substantive draft outline sent for the endorsement of the Prime Minister, which guarantee to decrease the mitigations by 5% or 18% (if underpinned via prosperous countries) contrasted to 2012 discharges level, for 2030 (Ebrahim, 2015). This situation motivates us to examine the CO_2 emission from Pakistan's power sector.

One of the most critical variables in combating CO_2 productions in Pakistan is a renewable source of energy. Renewable source of energy supply is growing at 47% annually with a current rate of 0.4 Mt. The total proved reserves of coal in Pakistan is 185.175 billion tons. This can be utilized for cheap energy creation. Therefore, Government of Pakistan has explored coal assets in Baluchistan, Punjab, KPK and AJK having warming esteem of 9000 Btu/LB -15000Btu/LB. According to Vision (2035) (2014), Coal Water Slurry (CWS) is very fetched successful and coal power generation cost is lesser than other technologies. Munir and Khan (2014) estimated that the energy deficit has resulted in financial losses between 2 and 3% of the GDP. Therefore, energy consumption plays an imperative role in the economic culture and economic growth of Pakistan.

The motivation and contributions of our study are recapitulating as follows: first, the study gives energy-related emissions in Pakistan by using data of 1978–2017 that has not been studied before; second, large number of existing researchers dealt with CO_2, have considered linear and non-linear regression; third, policy propositions are given to lessen the CO_2 related emissions in Pakistan. In this paper, we have tested using LMDI[1] (Logarithmic Mean Divisia Index) a technique that measures the emission changes and their effects in the existing periods. The study also adds Pakistan's prospect policies of the sustainable progress of the different sectors by setting up a long run symmetry association between Pakistan's CO_2 emissions and variables for example, such that carbon dioxide emanations each unit about fossil fuel consumption, change variables, energy strength, activity, and population. So, this research is an attractive accumulation to the writing of CO_2 emission alleviation mainly for Pakistan and other intermediary economies, especially within the framework of Pakistan (Vision, 2025, 2014; Vision, 2035, 2014; INDC, 2015).

By objectives, we have used different situations to answers the following questions (1) what the primary sources that are increasing CO_2 emission are? (2) What are the effects of climate change and global warming (floods & glaciers) on Pakistan? (3) What are the factors and policies implications that can reduce the CO_2 emission in Pakistan? (4) What are the cheap energy creation sources to fulfill the energy needs of the country? Remaining part of the study is ordered as:

Section 2 depicts a brief assessment of the relevant literature. Part 3 includes the methodology. Outcomes and discussions are given in Section 4. Conclusion, policy recommendations and limitations of this study are mentioned in section 5.

[1] LMDI method has been used to calculate the intensity effects of all variables.

2. Literature review

Climate change has become a severe issue in the world. The energy demand of each country is focused by many factors (i.e. population, wealth, culture, and climate, economic and social activities) which can be fulfilled by different energy types such as electricity, fossil fuels and modern technologies (Cassarino et al., 2018). All these sectors have monthly and annual demand for energy consumption. Due to the rapid economic growth and social revolution, the energy demand has increased during the past decades (Yu et al., 2018). Energy shortage, environmental filth, and global warming are becoming a challenge for the whole world. Due to the boost of industries around the globe and maximum usage of energy is the leading cause of CO_2 emission (Callan et al., 2009). Use of fuel energy has emitted CO_2 along with other GHGs and resulted in climate change (Wu and Chen, 2017). By the Intergovernmental Board on Climate Change IPCC (2006), distinctive energy forms have dissimilar carbon emission coefficients; and these emissions depend on the structure of energy. A perfect decomposition tool (LMDI) for analyzing power decomposition emerged in 2001 (Ang and Liu, 2001). According to Ang (2004) for the CO_2 emission improvement and the present policy implications IDA (index decomposition analysis) evaluate these factors. Lin and Du (2015) pointed out; the IDA model is an expressive approach that interacts energy efficiency enhancement. Laspeyres Index (LI) and Divisia Index (DI) are two types of IDA. Many researchers Zhang and Ang (2001); Lin and Du (2015) and Xie et al. (2016) have used different methods in many works of literature, but LI and DI are usually applied techniques. LI segregates the major prevail of every part of the aggregate sign and evaluates it by a constant base year while DI technique measures the outcome of every unit through statistics by the weighted mean logarithmic variations of pertinent variables. Ang (2004); Ang et al. (1998) and Liu et al. (2007) introduced LMDI under the umbrella of IDA. This method has been enhanced by Ang (2004) and utilized in IDA, counting as water use Zhao and Chen (2014), carbon emission Lin and Ahmad (2017); Wang and Yang (2016); Wang and Feng (2017); Zhang and Da (2015); Xie et al. (2015) and production of food (Kastner et al., 2012). This method is easily used in environmental analysis, cross country and regional energy due to its theoretical basis, characteristics and adaptation, etc. (Ang, 2004; Zhang and Ang, 2001; Ang and Zhang, 1999).[2]

Ang and Liu (2001) discover a technique based on decomposition properties and reliability in aggregation. The formula was named as LMDI II while the earlier named was as LMDI. This method is valuable over the whole decay methods, i.e. '0' or −ve values (Liu et al., 2007; Ang et al., 2003). The advantage of the LMDI technique, LMDI is used to decompose changes in CO_2 emanations (Lin and Ahmad, 2017). Analysis elements are then used to forecast the fossil fuel-related emissions. According to Cho and Sohn (2018); Lin and Ahmad (2017); Xie et al. (2016) and Akbostancı et al. (2011), LMDI is used for decomposition and deals zero value problem and also generally used in the analysis of CO_2 emissions. Additionally, Lin and Ouyang (2014) used the LMDI technique to discover the changes in CO_2 emissions non-metal industry of China during 1986–2010. They showed that labor efficiency is the key aspect which is growing CO_2 emissions. Therefore, LMDI has been considered as a decomposition method and can decay numerous issues without the residual problem. It can be categorized into two ways; additive and multiplicative. According to Ang et al. (1998 and Choi and Ang (2012), additive method decomposes the difference in the change of amount such as real GDP to many sources linked with this change while multiplicative method measures the ratio changes (Ang and Liu, 2001). So, according to our study multiplicative decomposition is beneficial in time series analysis whereas additive decomposition is helpful for time-wise analysis.

On the contrary, the existing review is based on two portions. First, we have examined the causal relationship between CO_2 emissions, population, energy consumptions, renewable energy, and GDP in different countries by different methods. Table 1a summarizes information and causality of this empirical literature. For example (Wang and Chen, 2005) for China (Sharif et al. , 2017) for Pakistan, and (Lise, 2006) for Turkey (Liu et al., 2007) for Hubei China, and (Ma and Stern, 2008) for China (Akbostancı et al., 2011) for turkey, and (Wang et al., 2013) for China Cement Industry. For improving climate (Larsen, 1992) for world emissions (Burniaux et al., 1992) for non-OECD, and (Steenblik and Coroyannakis, 1995) world emission reduction (Robaina-Alves et al., 2016) for Portugal tourist industry, and (Morgan, 2007) for energy subsidies. In the Pakistan development context, Wang et al. (2018); Mudakkar et al. (2013); Yousuf et al. (2014); Khan and Jamil (2016) and Irfan et al. (2018) performed simple policy imitations about subsidies and CO_2 emissions to overcome pollution. Subsidies wouldn't only useful points of interest over taxes but would also have bigger impetus effects. Comparing subsidizing LPG (Liquefied Petroleum Gas) with subsidizing piped natural gas, subsidizing LPG should be favored as it creates very price effective decrease in the use of solid fuels. If the government subsidizes only one clean fuel to decrease indoor air pollution, they should subsidize LPG in spite of natural gas. Therefore, renewable energy technologies (RETs) are the bridge to fulfill the distance between power demand and supply in Pakistan.

Secondly, we have tried to analyze the impact of internal and external factors in the context of environmental sustainability. According to Lin and Lei (2015), LMDI has become a standardized model which is generally used in the literature to conduct studies related to environmental problems and energy intensity. Table 1b shows the summary of different countries. For example (Xu et al., 2015) for Beijing water footprint (Geng et al., 2014); for China's waste water, and (Wang et al., 2013) for China's cement industry. Ang (2007) for France (Hettige et al.,1992); for U.S, and (Cropper and Griffiths, 1994) for 64 developing countries (Grossman and Krueger, 1995); for lesser developed cointries (Martınez-Zarzoso and Bengochea-Morancho, 2004); for OECD countries and focused on environment, energy use, population, labor wages, and pollution. Bekun et al. (2018) for 16-EU countries (Pulido-Fernández et al., 2018); for USA; (Oh et al., 2017); (Omri et al., 2018) for Saudi Arabia, and (Zoundi, 2017) for 25-African countries in measuring impacts of ecological sustainability. A study regarding earth dirtiness control and marine environmental security was conducted in mid of the 1990s in Xiamen China by (Lin et al., 2018). For the ocean consciousness, lack of carbon awareness and environmental protection, the local management managed special desks to get responses from individuals which created awareness for environmental protection. Lin and Wesseh Jr (2013) analyzed that future energy policies by 2020 of China are related to renewable energy for the development of GDP, RE, pollution reduction, energy structure and job-creating opportunities. As a result, whole planning was efficient; in-fact by 2020, regulation identifies 15% of its prime energy come from non-fossil fuel, while solar energy target has settled from 5 GW by 2015. Masud (2009) accomplished that clean energy projects have the great potential to develop the socioeconomic benefits, energy security, and lessened pollution and alleviate atmosphere change. In addition, Yazdanie et al. (2010) suggested providing cleaner energy

[2] LMDI introduced, utilized and enhanced by many researchers to measure the social factors such as energy consumption, production in industry, intensity, CO_2 emissions, environmental management and sustainable use of natural resources.

Table 1a
Summary of previous studies.

Authors	Countries	Duration	Methodology	Variables	Causality
Single-country studies					
Wang et al. (2005)	China	1957–2000	LMDI	CO_2 emissions-energy intensity	Y→X
				Renewable energy- CO_2 emissions	X→Y
Ang (2007)	France	1960–2000	Co-integration, VECM	CO_2 emissions-energy consumption	Y→X
Akbostancı et al. (2011)	Turkey	1995–2001	LMDI	CO_2 emissions-Fuel consumption	Y→X
Ma and Stern (2008)	China	1971–2003	LMDI	Population-CO_2 emissions	X→Y
Lise (2006)	Turkey	1980–2003	Kaya Identity	CO_2 emissions-energy intensity-GDP	X→Y
Liu et al. (2017)	China	1998–2005	CGE	CO_2 emissions-GDP	X→Y
Robaina-Alves et al. (2016)	Portugal	2000–2008	LMDI	CO_2 emissions-(CI,EI,SUB)	X→Y
Wang et al. (2013)	China	2005–2009	LMDI	GHG emissions-Fuel consumption	X↔Y
Lin and Ouyang (2014)	China	1986–2010	JCM	CO_2 emissions- labor	Y→X
Mudakkar et al. (2013)	Pakistan	1975–2011	GC	NE-Industrial GDP	X→Y
				NE-waste resources	X→Y
				NE- CO_2 emissions	X→Y
				Electric power-population	X↔Y
Yousuf et al. (2014)	Pakistan	2009–2011	WABEF	CO_2 emissions- Fuel sources	X↔Y
				Clean energy-carbon emission	X→Y
Khan and Jamil (2016)	Pakistan	1990–2012	LMDI	CO_2 emissions- energy consumption	X→Y
Sharif et al.,2017	Pakistan	1972–2013	CJ&JG&H	CO_2 emissions-Tourism	X→Y
Wang et al. (2018)	Pakistan	1990–2014	Two-stage least square method	CO_2 emissions-Renewable energy	X↔Y
	China			CO_2 emissions-GDP	X↔Y
Multi-country studies					
Martınez-Zarzoso and Bengochea-Morancho, 2004	OECD	1975–1998	EKC	CO_2 emissions-GDP	X→Y
Larsen (1992)	WR	1992	General analysis	Fossil fuel-CO_2 emissions	X→Y
Burniaux et al. (1992)	Non-OECD	1992	Emission analysis	Energy market-CO_2 emissions	X→Y
Steenblik and Coroyannakis (1995)	W&EC	1995	Net coal policies	Coal subsidies-environmental improvement	X→Y
Morgan (2007)	Global guess	2007	Report	Energy subsidies, GHG emissions	X→Y

Notes: X→Y shows unidirectional causality between the first variable to the second variable; Y→X shows unidirectional causality between second-first variables X↔Y shows bidirectional. VECM, vector error correction model; JCM, Johansen Co-integration method; GC, Granger Causality; LA-AIDS, Linear Approximate Almost Ideal Demand System model; CJ&JG&H, Co-integration, Johansen and Juselius and Gregory and Hansen; NE, Nuclear energy; W&EC, Western and European countries; WR, world report; EKC, environmental Kuznets curve.

Table 1b
Review framework in the context of environmental sustainability.

Methods	Major contributions	Investigations by objectives	
		Internal factors	External factors
Fixed effects model; GLS; EKC	Hettige et al. (1992) Cropper and Griffiths (1994) Grossman (1995) Martınez (2004)	Population growth and environment quality, agriculture and non-renewable resources. Air, water and solid wastage produce pollution. Income and wealth bow ecological problems. GHG is producing pollution and carbon emissions.	Deforestation and uncontrolled population. Economic growth.
LMDI	Ang et al. (2003)	Perfect decomposition knowledge.	Cross-regional world energy related to environmental applications.
VECM	Ang (2007)	Pollution effects the environment.	GDP and excess use of energy.
Energy analysis	Masud (2009)	Energy security and society.	Extreme weather changes, adaptation issues and energy infrastructure. Policy and financial environment.
LMDI	Xu et al. (2015)	Water food print.	Economic growth and technology
	Geng et al. (2014)	Industrial waste water pollution.	improvement off-set.
	Wang et al. (2013)	Imbalanced development, waste emissions. GHG emissions, cement industry. Extreme production.	Low carbon development policies.
LMDI	Lin and Lei (2015)	Food industry, Industrial activities and energy consumption.	Focus on the enhancement of energy efficiency and technology.
EKC	Zoundi (2017).	Income per capita.	CO_2 emissions.
LCA	Oh et al. (2017)	Building construction and pollutant emissions.	Design sustainability and CO_2 emissions
LA-AIDS model	Irfan et al. (2018)	Household energy demand. Burning of bio mass cause urban-rural life.	Subsidies on natural gas and LPG adoption can save environment. Government should interact.
EKC	Omri et al. (2018)	Environmental degradation, human development and per capita income.	GDP, CO_2 emissions and FDI.
SEM	Pulido-Fernández et al. (2018)	Tourist's activities cause environment sustainability.	Expansion of tourism.
PMG-ARDL	Bekun et al. (2018)	Decrease environmental pollution and cause ecological sustainability.	Renewable energy, natural resources and CO_2 emissions.

Notes: LCA: life cycle assessment; SEM (structural equation model); The Panel Pooled Mean Group-Autoregressive Auto regressive distributive lag model (PMG-ARDL).

to distant and country areas where people use biomass fuel. In addition, Asia Pacific region is highly defenseless to climate change, socioeconomic condition and demographic factors. Many countries in South Asia depends on thermal, coal and hydel power generation working under government authorities and few are private bodies (i.e. Pakistan, India and Nepal) (K.S Akash, 2017). The major

Table 2
Narrations of variables.[4]

Variables	Unit	Sources	Mean	Standard deviation
CO_2 Emission	Mt	The Statistical Review of World Energy	100.673	52.500
Fossil fuel consumption (FFC)	Mt	The Statistical Review of World Energy, Economic survey of Pakistan 1980, 2017	200823875	14171.23
Overall energy consumption (TEC)	Mt	Economic survey of Pakistan 1980, 2017	20798.54	14175.107
GDP of Pakistan	Mln (Rs.)	(WDI) World development indicators	12385481.42	8979579.275
Population of Pakistan	Mln	Economic survey of Pakistan 1980, 2017, WDI.	134.12	86.086

Mt, million tons; Mln Rs., million rupees in Pakistan; Mtoe, Million tons of oil equivalents.

identified problem between these countries is the lack of power generation and renewable technologies.

From Pakistan, few studies have been discussed above from the pollution and emission perspective. Several studies scrutinize the economy from the ecological point of view in distinctive areas. Ortolano et al. (2014) examine clean production and the firm's observance with Pakistan environmental, textile industries and leather tanneries. As a result of studying 80 tanneries and firms, the majority of firms adopt the renewable creation measures. According to the volume and firms participation, the overseas customers have encouraged the adaptation of cleaner energy production and managed ecological standard. Khan et al. (2016) inspect the association between air pollution, water resources, natural resources and use of energy. In the aspect of policy tool, carbon emission tax Dissou and Siddiqui (2014), forest carbon sinks Mukul et al. (2016), and clean apparatus are standard methods for CO_2 mitigation (Liu et al., 2017). It concluded that use of energy and water resources have an optimistic association with air pollution in short-run and long-run while natural resources don't influence the air contamination.

The literature on the association among CO_2 emissions and other environment influential factors are analyzed and quantified by numerous researchers. Many studies explore the relationship between water, population, climate, economic, energy efficiency, CO_2 emissions, fossil fuel consumption, renewable energy, and forecasting effects as discussed in literature, Tables 1a and 1b. Only a few researchers pay attention in the relationship among CO_2 emissions, environment sustainability and social impetus. Our study on the analysis of energy related emissions contribute to the literature generally in developing countries and especially in Pakistan. Besides, an LMDI decomposition technique is embedded to explore the effects of carbon emissions and other important environmental factors such as energy sources, GDP and population from 1978 to 2017. Furthermore, we designate scenario analysis to forecast CO_2 emissions from 2017 to 2035. For our understanding in exploring the relationship among ecological factors and carbon emissions in Pakistan is the first study in its nature.

3. Methodology and data source

3.1. Variables and data collection

The research used data for 1978–2017; we select a certain period by the convenience of time series data. CO_2 emissions are considered as the overall emissions of CO_2 (Mt). Economic growth, population, energy consumption, and fossil fuel consumption are taken as (Table 2). The factors are chosen by the Kaya Identity 1990, and these are; CO_2 emission, Coal consumption, Natural gas production, Natural gas consumption, Oil consumption, electricity generation, renewable energy and population in Pakistan. Diagram, variables, and data sources are given in Fig. 1 and Table 2.

3.2. Model description

Recent empirical studies such as (footnote 3) used the LMDI technique to check the relationship between different variables. Following the existing literature, the Kaya identity equation method is applied to analyze the effects of CO_2 emissions as below:

$$CO_2 = \text{Population} \cdot \frac{\text{GDP}}{\text{Population}} \cdot \frac{\text{Energy}}{\text{GDP}} \cdot \frac{CO_2}{\text{Energy}} \quad (1)$$

$$CO_2 = \sum_{i=1}^{9} P \cdot \frac{G}{P} \cdot \frac{E}{G} \cdot \frac{C}{E} \quad (i = 1....9) \quad (2)$$

Where C stands for CO_2 emissions, E for energy utilization, P for population, G for GDP, F fossil fuel emissions[3] and i is the number of factors.

According to Kaya identity 1990s, emissions related factors are:

$$CO_2 = \frac{CO_2}{FFC} \cdot \frac{FFC}{TEC} \cdot \frac{TEC}{GDP} \cdot \frac{GDP}{Pop} \cdot Pop \quad (3)$$

- The first entry on the right side of the equation is called carbon intensity, which indicates the emission amount generated by per unit fuel consumption. If the numerical value is small, the CO_2 Emission will also be low. It will be more efficient, and utilization structure will be good if an amount is zero or consumption of fossil fuel is close to zero.[5]
- The second item shows the substitutions based on fossil fuel and energy consumption. If the numerical value is lesser then the results will be considered as an efficient.
- The third item can be expressed as energy density, which shows the total energy consumption per unit change GDP. If the numerical value is small, the energy utilization will be more efficient.
- The fourth item shows the GDP per capita. If the numerical value is high, the scale of an economy will also be high, and the source of revenue will be productive.
- The fifth item is based on population. If the numerical value is high, then the impact on CO_2 Emission will also be higher.

By using the change rate as mentioned above, we acquire the

[3] Since we have used fossil fuel energy consumption variables, we have not considered electricity because it is considered as clean. The study adopts fossil fuel and energy-related CO_2 emissions related fuels. F is emissions from Human sources (Human sources include production of anything, deforestation, combustion of fossil fuels such as coal, oil, gas and natural gas) and 'i' comprise, aviation gasoline, motor gasoline, oil, kerosene, diesel, and residual fuel oil, LPG, LNG, Natural Gas and Coal are taken as fossil fuel.

[4] The variables FFC, TEC, GDP, Pop and CO_2 emissions (given in Table 2) which described to measure the strength and effects. These are taken from natural gas, nuclear energy, coal, oil and renewable energy (source: Statistical Review of World Energy).

[5] One of the measures to lessen CO_2 Emission is to convert the mode of energy use from fossil fuel resources to clean energy resources such as solar, wind, thermal, biomass etc.

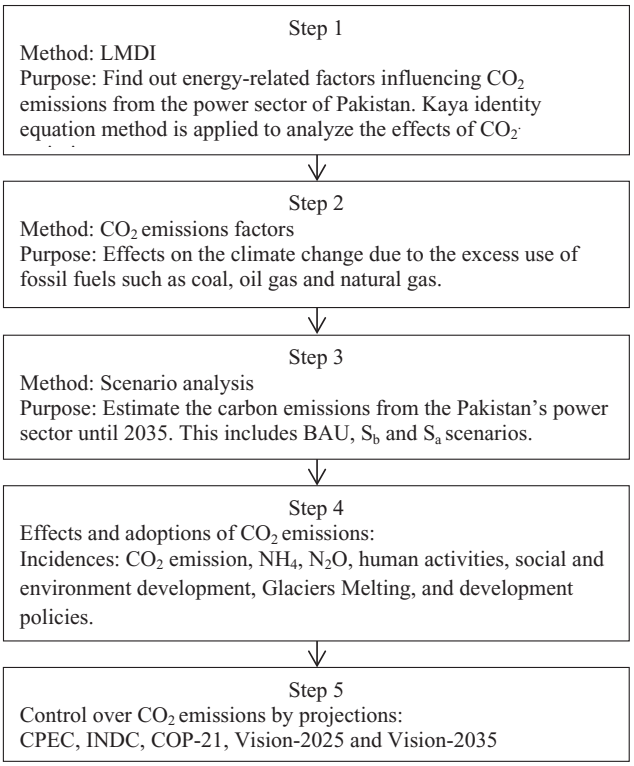
Step 1
Method: LMDI
Purpose: Find out energy-related factors influencing CO_2 emissions from the power sector of Pakistan. Kaya identity equation method is applied to analyze the effects of CO_2.
Step 2
Method: CO_2 emissions factors
Purpose: Effects on the climate change due to the excess use of fossil fuels such as coal, oil gas and natural gas.
Step 3
Method: Scenario analysis
Purpose: Estimate the carbon emissions from the Pakistan's power sector until 2035. This includes BAU, S_b and S_a scenarios.
Step 4
Effects and adoptions of CO_2 emissions:
Incidences: CO_2 emission, NH_4, N_2O, human activities, social and environment development, Glaciers Melting, and development policies.
Step 5
Control over CO_2 emissions by projections:
CPEC, INDC, COP-21, Vision-2025 and Vision-2035

Fig. 1. Flowchart of overall study for Pakistan.

following equations.

$$CO_2^t = \frac{CO_2^t}{FFC^t} \cdot \frac{FFC^t}{TEC^t} \cdot \frac{TEC^t}{GDP^t} \cdot \frac{GDP^t}{Pop^t} \cdot Pop^t \quad (4)$$

As indicated by the equations, change in CO_2 emission in a country or area may be classified into the following aspects.

$$CO_2 = CI.Sub.EI.AC.Pop \quad (5)$$

equation (5) presents five policy instruments for CO_2 Emission Reduction. To check out the CO_2 Emission effects, LMDI method is used. The LMDI have been broadly utilized in the past work to perform research on environmental problems such as 'EI' (Lin and Lei, 2015). LMDI method is used to measure the changes in industrial, transportation sectors, etc. CO_2 emissions in Pakistan, and can also be used to check emissions changes. To check the effects of the period from 1978 to 2017 of all related factors with CO_2 to ΔCO_2 ranges from 0 to 1 can be used in below equations.[6]

$$\Delta CO_2 = CO_2\,(1) - CO_2\,(0) \quad (6)$$

Because there is no residual factor so, the effects can be measured as:

$$\Delta CO_2 = CO_2(1) - CO_2(0) = CI_{eff} + Sub_{eff} + EI_{eff} + AC_{eff} + Pop_{eff} \quad (7)$$

$$\Delta CO_2 = CI_{eff} + Sub_{eff} + EI_{eff} + AC_{eff} + Pop_{eff} \quad (8)$$

$$CO_2(1) = CO_2(0) + CI_{eff} + Sub_{eff} + EI_{eff} + AC_{eff} + Pop_{eff} \quad (9)$$

$$CO_2(0) = CO_2(1) - CI_{eff} - Sub_{eff} - EI_{eff} - AC_{eff} - Pop_{eff} \quad (10)$$

- CI_{eff} is the variation in CO_2 decays per unit of FFC.
- Sub_{eff} emanations due to the change in the share of 'FF' in TEC.
- EI_{eff} is the is the emission of (TEC) per unit of GDP.
- AC_{eff} is the variation in emanation due to GDP per capita.
- Pop_{eff} emissions changes due to the total population of Pakistan given in equation (15).

By using the LMDI formula, the effects of each factor can be calculated from Table 3.

$$CI_{eff} = w.\ \ln\left[\frac{CI(1)}{CI(0)}\right] \quad (11)$$

$$Sub_{eff} = w.\ \ln\left[\frac{sub(1)}{sub(0)}\right] \quad (12)$$

$$EI_{eff} = w.\ \ln\left[\frac{EI(1)}{EI(0)}\right] \quad (13)$$

$$AC_{eff} = w.\ \ln\left[\frac{AC(1)}{AC(0)}\right] \quad (14)$$

$$Pop_{eff} = w.\ \ln\left[\frac{Pop(1)}{Pop(0)}\right] \quad (15)$$

Where,

$$W = \frac{CO_2(1) - CO_2(0)}{\ln[CO_2(1)/CO_2(0)]} \quad (16)$$

From equations (11)-(15) different factors effects can be calculated. Data has been collected from the related sectors of Pakistan and arranged according to the five years gap as 1978 to 1982, 1983 to 87, 1988 to 1992, 1993 to 1997, 1998 to 2002, 2003 to 2007, 2008 to 2012 and 2013 to 2017.[7] We have applied data arrangement technique used by Pakistan bureau and national economic plan and also used by (Lin and Ahmad, 2017; Lin and Moubarak, 2013; Lin and Ouyang, 2014).

4. Results and discussion

4.1. ΔCO_2 (change in CO_2) due to time effect

It can be seen that the power sector's CO_2 emissions during the period have been showing an increasing trend (Table 3 and Fig. 2). From 1978 to 1982, the growth in CO_2 emissions was 34.2 million tons, with the increase in substitution, activity and population factors amounting for 0.84 million tons, 4.61million, and 1.04 million respectively. Carbon intensity and energy intensity elements accountable for the reduction in CO_2 emissions and their contribution were −1.39 Mt and −3.006 Mt respectively. The major factors causing the increase in CO_2 emissions in this period were the growth of activity effects (AC_{eff}) and the rise in population effects (Pop_{eff}). AC_{eff} increased from 104 million in 1978 to 112.1

[6] Our method LMDI has produced good results for CO_2 emissions and is beneficial for the future research. Few economists also believe that cob Douglas function provides better output in the analysis of CO_2 emissions.

[7] We have arranged data with 5 years interval according to the national economic plan of Pakistan which is more convenient to explore many years' data. https://sites.google.com/site/maeconomicsku/home/economic-planning-in-pakistan.

Table 3
The decay of CO_2 outflow changes from fossil powers utilization.

Period	Emission Change	CI_{eff}	Sub_{eff}	EI_{eff}	AC_{eff}	Pop_{eff}
1978–82	34.1993	−1.385269377	0.837049837	−3.005968546	4.608182047	1.037236247
1983–87	54.325	0.163174438	1.480428871	−3.82488474	6.157598071	3.000903077
1988–92	62.47	1.100133816	2.029128989	−6.091305203	9.455482493	4.726424832
1993–97	54.246	0.89400883	1.992269141	−5.216173829	9.019266776	5.04765459
1998–2002	60.17	−0.980578533	2.501686017	−1.757960077	8.11290542	6.544223168
2003–07	151.609	−5.661716661	6.698102106	−9.008417864	32.56496795	18.15928732
2008–12	1.279	−0.05708733	0.057141893	−0.137587095	0.329619439	0.173031348
2013–17	164.986	53.72268942	−1.634785614	−70.37736671	45.10000059	23.94706645
1978–2017	692.32	225.4330206	−6.859944337	−295.3199576	189.2501934	100.4875143

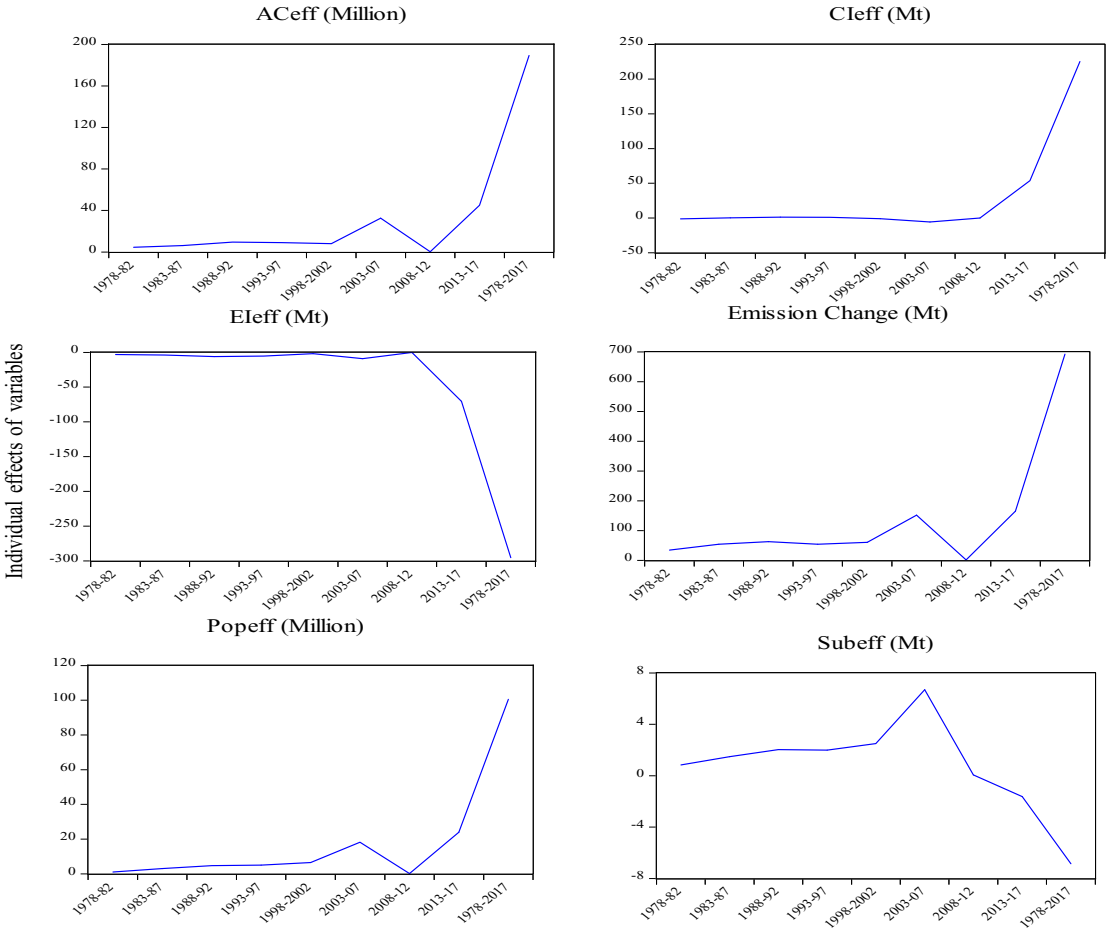

Fig. 2. Graphical representation of decomposition of CO_2 emission through fossil FFC in Pakistan.

million in 1982. Amongst the factors increasing emanations, the impact of the population was not significant.

During the period 1983–1987, CO_2 emissions increased by 54.3 Mt. AC_{eff} and Pop_{eff} were the most significant factors causing the increase with the contribution of 6.2 million and 3.0009 million. Energy intensity effect (EI_{eff}) was negatively related to a decrease in CO_2 emissions by −3.825 Mt. The influence of EI_{eff} was not significant. From 1998 to 1992, ΔCO_2 increased by 62.47 Mt while AC_{eff} and Pop_{eff} were the highest factors with the share of 9.46 m and 4.73 m. Only EI_{eff} was negatively to decrease in emissions by −6.091 Mt ΔCO_2 emissions increased by 54.25 Mt in 1993–1997 due to increases in AC_{eff} and Pop_{eff} by 9.02 M and 5.05 M respectively. EI_{eff} was counted as significant with an amount of −5.22 Mt. This is because Pakistan generally depends on thermal sources; the surge in oil costs demoralized the rising energy consumption. According to Lin and Ahmad (2016), the decrease in emission (8.22 Mt in 1997) results is proof of fuel substitution from petroleum products to gas. From 1998 to 2002, ΔCO_2 increased by 60.17 Mt due to increasing in AC_{eff} and Pop_{eff} by 8.11 M and 6.54 M. CI_{eff} and EI_{eff} were negatively related to CO_2 emissions with the share of −0.981 Mt and −1.758 Mt. During 2003–2007, CO_2 emissions increased by 151.61 Mt due to causing factors of AC_{eff} and Pop_{eff} and Sub_{eff} with the contribution of 32.56 M, 18.16 M and 6.69 Mt. The CI_{eff} and EI_{eff} were negatively affecting in decreasing CO_2 emissions with the portion of −5.66 Mt and −9.008 Mt. In 2008–2012, the change in CO_2 emissions increased by 1.28 Mt and decreased by 150.33 Mt than the previous period. This is because of minimum increase in AC_{eff}, Pop_{eff} and Sub_{eff} while CI_{eff} and EI_{eff} decreased emissions by −0.06 Mt and −0.14 Mt. Energy intensity has a positive impact due to 'TEC' per unit change in GDP while GDP

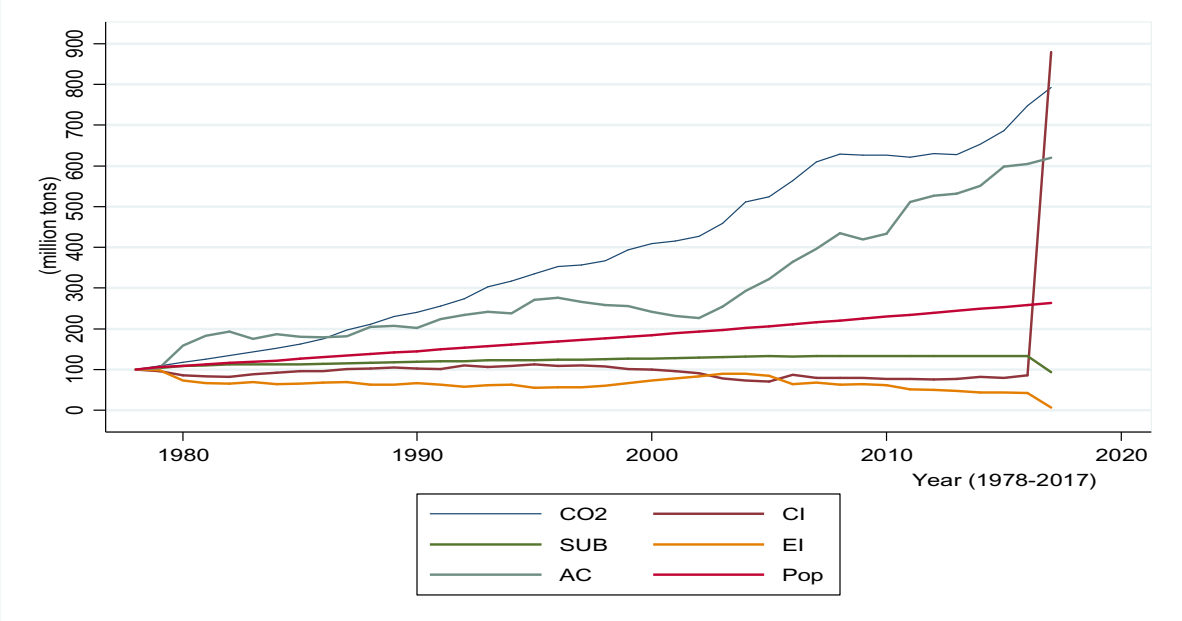

Fig. 3. Combined impacts of donors to fossil fuel related CO_2 outflows in Pakistan on current year and the base year 1978.

per capita (AC) has a positive role in all years. Total energy mix (of 85.2%) of Pakistan is reliant on oil, LPG and natural gas (Sadiq, 2018). Therefore, the low consumption of oil and use of clean energy alternatives can decline and play an important part in falling total CO_2 emissions. Finally, during 2013–2017 ΔCO_2 emissions increased by 164.98 Mt. CI_{eff}, AC_{eff} and Pop_{eff} were the largest factors causing in increasing CO_2 emissions with the contribution of 53.72 Mt, 45.100 M and 23.95 M. Finally, in the period 1978–2017, the CO_2 emissions increased by 692.32 Mt with which about AC_{eff} and Pop_{eff} factors contributing approximately 189.25 M and 100.49 M. Through this analysis of each period shows that AC_{eff} and Pop_{eff} are the most important driving factors for the increase in CO_2 emissions in Pakistan's power sector while the decrease in CI_{eff} and EI_{eff} are the most significant reasons for the decline. This is due to the unstable structure which has not changed yet. To maintain the rapid growth of the economy, coal, which has low price and large-scale reserve, is an ideal energy source and maximum emissions can be controlled in Pakistan.

4.2. Collective effects of ΔCO_2 emanations

Fig. 3 shows the aggregate impacts of all factors (1978 as base year) for Pakistan discussed in (equations (1)–(5)). As shown in Fig. 3, from 1978 to 2017, CO_2 emissions in all years increased significantly with the amount of 100 Mt to 792.32 Mt with a growth rate of 12.62%. Activity (AC) and Population (Pop) has continuous effects on increasing CO_2 emissions throughout the entire period with 16.13% and 37.95%. CI and EI have a significant impact on decreasing CO_2 emissions with 11.38% and 16.97% during the period of 1978–2017. So, the major supporter to the turn down in CO_2 emissions in Pakistan is AC_{eff} and Pop_{eff}. The element of energy strength effect has a negative achievement on the variations in fossil energy-related emissions. The oil trouble encouraged global financial problems in 2007–09. 'EI' has observed a quick declining movement, and as a result, the involvement of energy intensity effect to variations in CO_2 emissions become negative in 2010 and remain at a low level (−0.13 Mt) between 2008 and 2012. After that due to new political party initiatives, there has been increased in some renewable and solar energy projects with the cooperation of China and has created a positive change in emissions (see Figs. 3 and 4). However, after the energy policy of 1995, the boost in petroleum goods to power generation significant equalize the negative input of gas spending to alter in CO_2 emissions.

The coal projects in Pakistan will fulfill the energy needs signed by China 'CPEC'. So, the results between economic growth (EG) and CO_2 emissions can be enlightened by the fact that boost in CO_2 emission is linked with higher consumption of oil, coal, fertilizers and other energy concentrated economic activities (Mirza and Kanwal, 2017). In general, to improve the environmental factors in Pakistan, the administration desires to strengthen some part of renewable energy by coal and solar which are less costly for the production and supply. Although conceding that the energy sparing is the elementary medication to decrease the emission, currently the global policies to lessen the emanation also comprises the

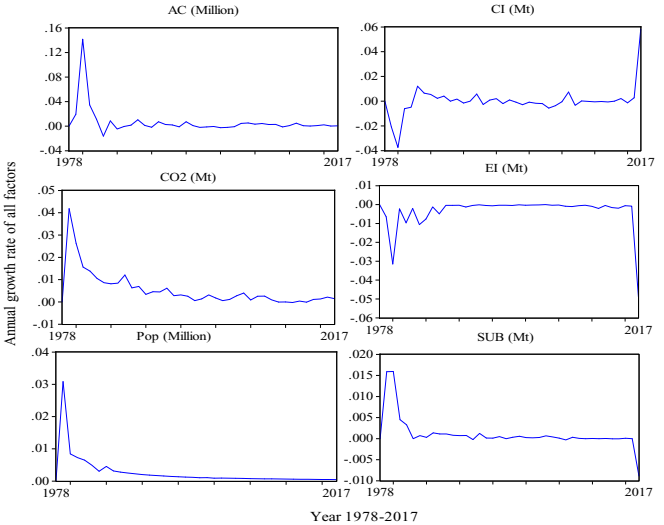

Fig. 4. The Average annual growth rate of impacts of contributors to fossil fuel-linked CO_2 productions in Pakistan from 1978 to 2017.

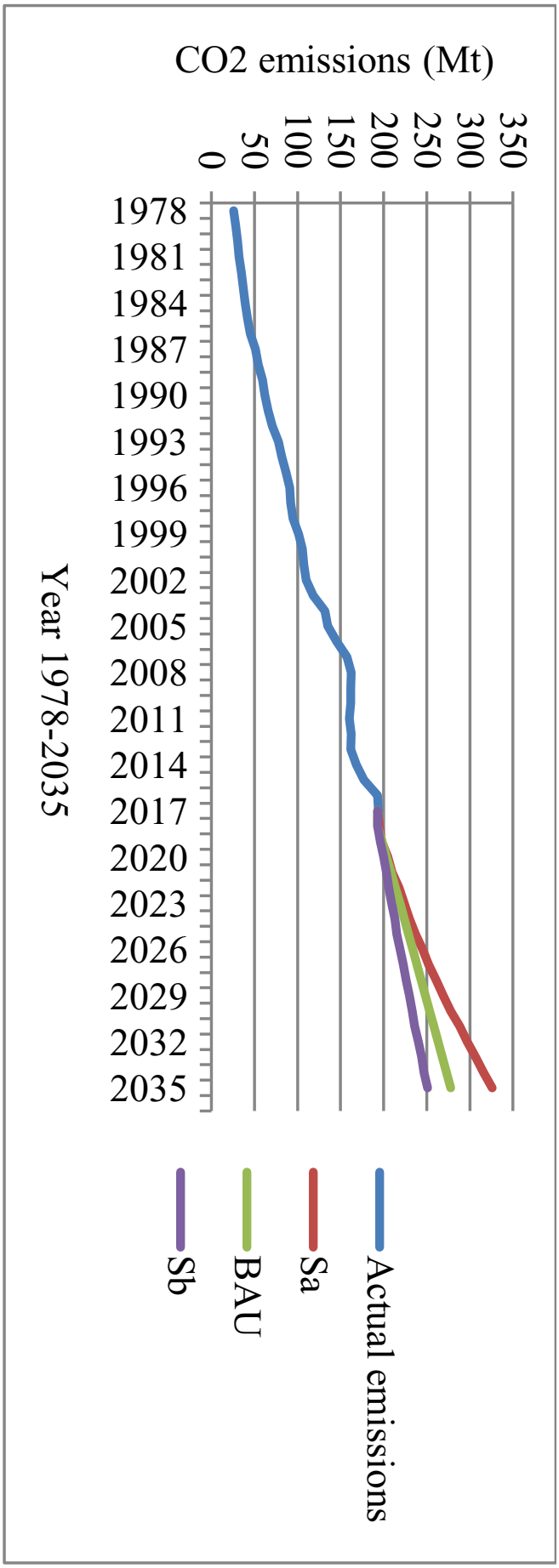

Fig. 5. Scenario analysis of actual and estimated fossil fuel related emissions from 1978 to 2035.

shortest technique of carbon imprison and storage and substitute materials (Benhelal et al. 2013).

4.3. Comparison of energy-related CO_2 emission

According to the (equation (5)), the annual average growth rate of each factor is shown in Fig. 4. The trend of Activity (AC) increased at maximum level with 0.14% in 1980 and then decreased with −0.0163% in 1983. The trend in population contributed to a growth rate of 37.95% from 1978 to 2017. The direction of AC is rising due to the continuous growth in business spread and population. Similarly, the trend of carbon intensity was favorable in reducing CO_2 emissions till 2015 and increased suddenly by 2.32% in 2017. Overall, energy intensity had decreased emissions and grew at an extreme level in 2017 by 2.3% while substitution has a mixed effect due to the availability of mixed fuel. The average results raise 0.006% of carbon intensity due to ΔCO_2 emissions per unit increase in fossil fuel consumption while 0.0023% is the average increase in energy intensity due to TEC and GDP during 1978–2017. Fig. 4, shows long-run growth of each factor and reveals that AC_{eff} Pop_{eff} and Sub_{eff} are significantly positively related to economic growth and CO_2 emissions. Due to GDP, energy and climate targets, the government of Pakistan needs more efforts. Therefore, we calculate fossil fuel estimation related to CO_2 from 2018 to 2035. And this is line with Government of Pakistan goals in Vision 2014 (Vision, 2025, 2014).

4.4. Scenario analysis and growth

To estimate the prospect power-related CO_2 emission and possible results, we construct three scenarios with the intent to provide the comparative outcomes from the evidence of these studies/scenarios (Lin and Ahmad, 2017; Lin and Ouyang, 2014; Yousuf et al., 2014; Ou et al., 2010; Zhang et al., 2012). In this analysis, all the existing variables and fluctuating the rate of every element for all scenario is given. In Tables 4 and 5, BAU (business as usual), S_a (scenario a) and S_b (scenario b) are used to find out the outcome under limitations. BAU (also called baseline scenario) is centered on historical growth movement of each variable in Fig. 5. The average growth rates for the sample period of 1978–2017 are taken as a baseline scenario.

These are:

1. BAU: This is called a baseline scenario which includes 1978–2017 as a base year, and we will use it to find out the trend.
2. This scenario is the higher emission scenario = g (growth) of each variable >2% of BAU.
3. The third scenario is the Lowest emission scenario = g of each variable <2% of BAU.

Through, these scenarios can compare CO_2 emissions and energy utilization in Pakistan. This scenario is based on the hypothesis given in Table 4. So the overall activity is increasing due to the population and intensity of CO_2 emissions. CI can be reduced by using renewable alternatives and modern technologies. Fig. 5 presents CO_2 emissions from FFC (fossil fuel consumption) in the power sector of Pakistan. It is foreseen that CO_2 emissions of Pakistan in 2035 will be 277.8564 Mt, in S_a will be 326.0021 Mt, and 251.003 Mt in S_b. Compared with the S_a emissions reduce by 48.1457 Mt and 74.9991 Mt under the BAU and S_b respectively. Similarly, the predictions in 2025 will be 229.00004 Mt while S_a will be 237.024 Mt, and 215.012 Mt in S_b. Linked with the S_a emissions reduce by 8.024 Mt and 22.012 Mt under the BAU and S_b respectively. According to Fig. 5, the results related to carbon emissions with the scenarios can be seen. The benefit of the given scenario is that we can have a comparative study of the likely outcomes of carbon emissions. Through this, diverse energy policies and CO_2 emissions can be equated (see 5.2).

Table 4
Proposed hypothesis of variables in %.

Scenario	CI	Sub	EI	AC	Population
S_a	−0.000624	0.00123	−0.00129	−0.0003	0.00813
BAU	−0.0008	−0.0002	−0.0001	−0.00051	0.00492
S_b	−0.000934	−0.0004	−0.00032	−0.000731	0.00249

Table 5
Estimation of CO_2 emissions in Pakistan power sector (million tons).

Year	2025	2035
Scenario a	237.024	326.0021
Business as usual	229.00003	277.8564
Scenario b	215.012	251.003

4.5. Emission potential from period 2018–2035

To estimate future emissions perspective, we have used forecasted values of period 2018–2035. Using the output in (Fig. 6), the conceivable comes about CO_2 emissions, Pop, CI and FFC (fossil fuel consumption). By equations (1)–(4), CO_2 emissions and other factors can be calculated for the given period. Fig. 6 measured the potential of fossil fuel-related CO_2 emissions from the power sector of Pakistan is 203.5 Mt in 2020, 229 Mt in 2025, 253.5 Mt in 2030 and 277.9 Mt in 2035. This is evident from (Figs. 3 and 4) under aggregate emissions and Tables 4 and 5 shows the current potential of all factors under BAU scenarios. It is forecasted that the growth expression of each element, AC, CI, CO_2, and substitution will be 219731.9 M, 0.012 Mt, 277.9 Mt and 0.994 Mt while Population and EI will be 20.55 M and 0.00065 Mt in 2035. As per Table 3 during intervals of 1978–2017 and Fig. 6 found that improvement in $\frac{GDP^t}{Pop^t}$ and $\frac{FFC^t}{TEC^t}$ are the main factors affecting in increasing CO_2 emissions while over future population and $\frac{TEC^t}{GDP^t}$ will contribute a sustainable development in improving productivity and management level.

5. Conclusion and policy recommendations

5.1. Conclusion

This study analyzes the CO_2 emission from the power sector of Pakistan due to energy crises. The LMDI tests and Kaya identity applied to examine the change in the CO_2 emissions of Pakistan's power sector and determine the influencing factors during 1978–2017. We then estimate CO_2 emissions from 2018 to 2035 for the reduction potential of Pakistan as given in goals of COP-21 and (INDC, 2015; Vision, 2035, 2014). The results show that AC_{eff}, Sub_{eff} and Pop_{eff} are positively affecting in increasing CO_2 emissions while CI_{eff} and EI_{eff}, have adverse effects in decreasing emissions of Pakistan. Increase in clean energy technology causes a sharp decrease in CO_2 emissions while the use of fossil fuel, biomass, labor productivity, the boost in transport and industries causes an increase in CO_2 emissions. The conclusion is in line with previous researchers (Lin and Ahmad, 2017; Yazdanie et al., 2010; Liu et al., 2017; Ma and Stern, 2008). In addition, the influencing factors and CO_2 emissions have a long-run relationship and exist. Furthermore, to fulfill the rising demand of energy, the government must ensure the renewable and efficient energy technologies (i.e. clean energy, hydroelectricity, solar, wind, wave, geothermal and

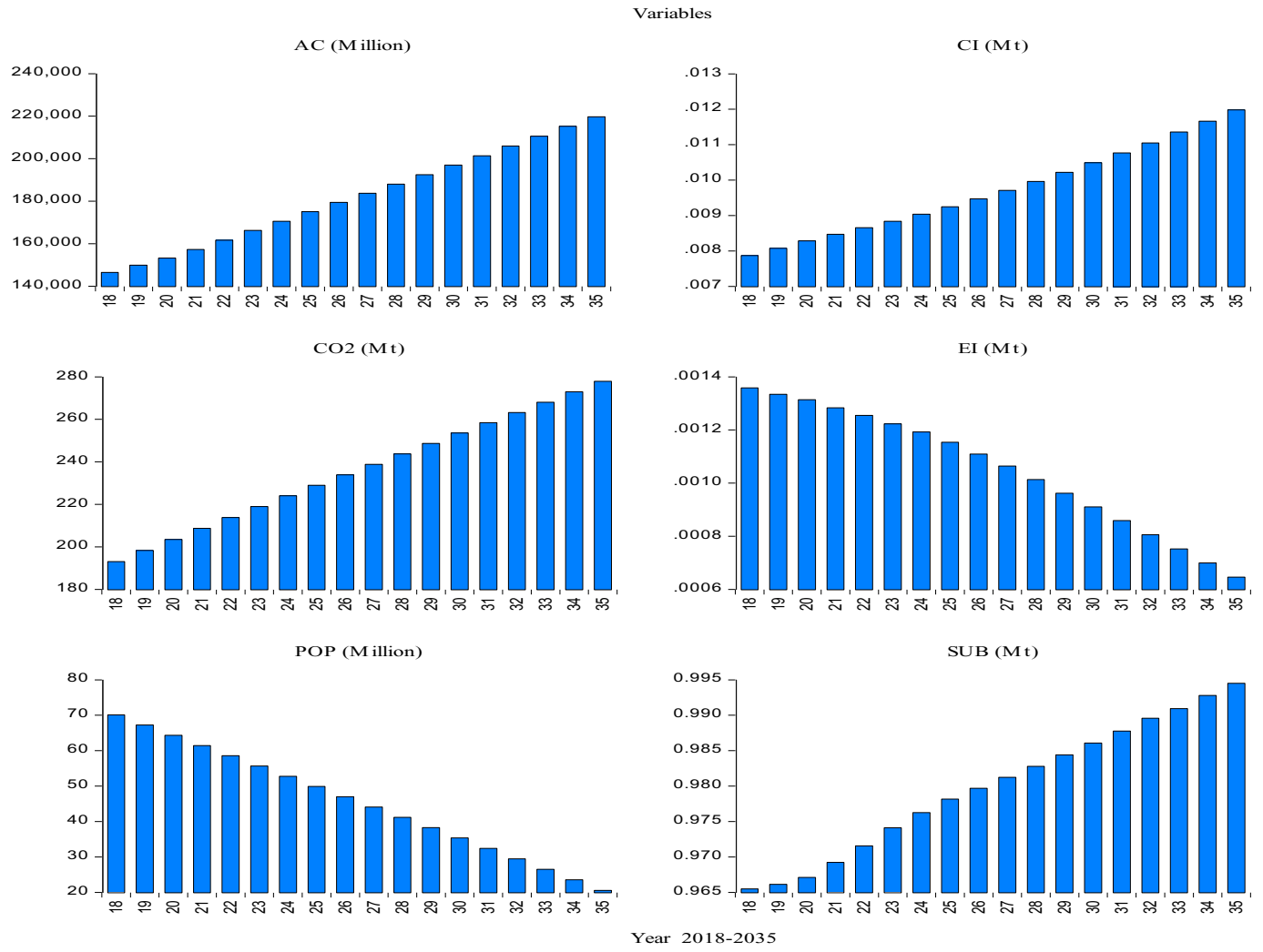

Fig. 6. Predicted graphs of individual increase/decrease in factors.

tidal power) means in the suitable areas. It can be expected that the improvement in renewable energy sources instead of Oil, coal and gas, the CO_2 emissions can be reduced.

5.2. Policy recommendations and suggestions

With increasing global climate change, CO_2 emissions will increasingly become a constraint on economic growth. How can Pakistan develop the power industry while also reducing CO_2 emissions? According to this research, the following steps should be taken.

Firstly, according to empirical findings economic growth, population, and social revolution have steadily become the major cause of energy consumption (Yu et al., 2018). Therefore, due to the absence of energy means and maximum use of fossil fuel causes CO_2 emissions. For this, the Vision (2025) (2014) and Vision (2035) (2014) will constitute a significant challenging part in lessening CO_2 emissions in Pakistan.

Secondly, Lin and Ahmad (2016) modification of power costs and alternative renewable, import for domestic energy and greenhouse gases (GHGs) emissions in Pakistan are essential ways to attain this objective. CI_{eff} and EI_{eff} policies do impact the level of emissions let out into the atmosphere.

Thirdly, Saleem et al. (2015) analyzed the carbon tax policies from Pakistan's energy sector with time frame-work to overcome emissions. Better results can be obtained by utilizing cleaner energy in the transportation and urban areas of Pakistan. By the collapse of energy utilization via every fuel category (such as coal, crude oil, gasoline, kerosene, diesel oil, fuel oil, and natural gas) CO_2 emissions can be reduced (Lin and Ahmad, 2017; Li and Lin, 2015). In developing countries like Pakistan, these renewable technologies can promote sustainable energy that can be helpful in local and global industries in Pakistan (Shahbaz et al., 2013).

From the outcomes of the ramify analysis, it is suggested that CO_2 emissions can be diminished by (i) encouragement in technological innovation and enhancement the efficiency of power utilization (ii) improvement in energy consumption structure (iii) implementation of low carbon life (iv) and levitating the consciousness about energy saving and emission reductions. Finally, population growth will rouse CO_2 emissions that can be controlled by a little consistent contributions by changing life style such as switching off extra electric appliances, using less electricity consuming bulbs, wastage of water, small distance driving instead of walking, leakage of mines, agriculture production, excess of old transport, commercial and residential buildings.

5.3. Limitations, key points and gaps

From the recent relevant literature on the energy-related CO_2 emissions from the power sector of Pakistan. In reality, each

country has its distinctive background. Therefore, according to the regional scale, Pakistan has certain limitations. According to the results, the change in population and GDP are crucial factors in changing CO_2 emissions. An efficient system limits the range of causal technologies that be considered to satisfy production functions and developing projects. Future study may look at the provincial or rural/urban areas to investigate the relationship among related factors. Firstly, to perform a well-supported calculation, the availability of data is necessary. Secondly, the technical efficiency and renewable energy had a significant effect on the national carbon emissions. Thirdly, the power plants, human capacity and financial supports can play an imperative role over a future period. However, the empirical evidence from Pakistan may not apply to other countries in the region due to level and economic development pattern, technology advancements and specific influencing factors. Thus, we conduct a realistic study with a rich sample of (40 years) for the characteristics of CO_2 emissions in the power sector of Pakistan.

Acknowledgements

The paper is supported by Report Series from Ministry of Education of China (No.10JBG013), and China National Social Science Fund (No. 17AZD013).

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